APPLICATION

FOR

UNITED STATES LETTERS PATENT

TITLE: A HEAT EXCHANGER PLATE, A PLATE HEAT EXCHANGER AND A METHOD FOR MANUFACTURING A HEAT EXCHANGER PLATE

APPLICANT: BERNT ERIK TAGESSON

CERTIFICATE OF MAILING BY EXPRESS MAIL

Express Mail Label No. EF353809172US

January 26, 2005

Date of Deposit

A heat exchanger plate, a plate heat exchanger and a method for manufacturing a heat exchanger plate

The invention refers to a heat exchanger plate for a plate heat exchanger, wherein the plate includes a heat transfer area and a border area, which is located outside the heat transfer area and which extends along and delimits the heat transfer area. The invention also refers to a plate heat exchanger including a plurality of such plates. Furthermore, the invention refers to a method for manufacturing a heat exchanger plate, including the steps of: providing a sheet, cutting and forming the sheet to a heat exchanger plate with a heat transfer area, which has a number of open portholes, and a border area, which is located outside the heat transfer area and which extends along and delimits the heat transfer area,

SE-B-548 806 discloses a plate heat exchanger with such heat exchanger plates. The heat exchanger plates are kept together to a plate package by means of tie bolts.

Today heat exchanger plates are manufactured by pressing to a desired shape and by cutting for removing unwanted portions, for instance the portholes. The gaskets, which are used between the heat exchanger plates in the plated heat exchanger, are manufactured separately, for instance by compression moulding or injection moulding. The gaskets are usually manufactured in any ~~relatively hard rubber material, such as nitrile, EPDM or fluorine~~ rubber. Thereafter, the complete gasket is attached to the complete heat exchanger plate. Preferably, the gasket is attached to the heat exchanger plate by gluing. The gasket may also include various guide members, for instance so called T-tabs, which extend outwardly from the gasket and which are pressed to attachment in corresponding grooves in the heat exchanger plate. Previous

gaskets usually had a substantially rectangular cross-section shape whereas gaskets in recent years have been given a roof-like, acute cross-section shape for the upper surface of the gasket, i.e. the surface which faces and abuts the adjacent heat exchanger plate.

Even if such previously known, separately moulded gaskets have excellent sealing properties and high reliability, they are associated with certain disadvantages. The mounting of the gaskets is a time-consuming manual work, which is ergonomically tiring and difficult to automatise. Large quantities of gaskets of various dimensions have to be available in stores. The manufacturing of gaskets in various dimensions requires large investments in different moulding tools, which also means that the cost for modifying a gasket becomes high. The gaskets may not be individually adapted to different plate thickness or required working pressures in different applications. During mounting of the plates to a plate package, an accurate checking that the gaskets are properly positioned, for instance that all T-tabs are correctly provided in the respective groove, is required. The gaskets are not reusable in connection with service of a plate heat exchanger, since they often break, have shrunk etcetera. Consequently, the gaskets have to be removed and replaced on every service occasion when the plate package is demounted.

DE-A-23 59 978 discloses a plate heat exchanger of another type with plates of glass or any similar silicate material. Between the plates along the edges, strings of a combined sealing and adhesion material including silicon are provided. These strings are arranged successively in such a way that first strings and distance pieces are applied on a first plate. Thereafter, a second plate is applied to the distance pieces and the first strings. Second strings and distance pieces are then applied to the second plate, whereupon a third plate is applied to the second strings etcetera. When the plate package has been mounted in this manner, the sealing and adhesion material is cured, whereupon the distance pieces are removed.

DE-A-39 05 066 discloses a heat exchanger module with thin metal foils that are stacked on each other with intermediate distance elements including an edge member and a fabric. The edge member includes sealing means, which may consist of different polymer materials such as for instance silicon caoutchouc, thermoplastic resins etcetera.

SUMMARY OF THE INVENTION

The object is to simplify the manufacturing of plate heat exchangers and remedy the above-mentioned disadvantages.

This object is achieved by the initially defined heat exchanger plate, which is characterised in that a curable polymer material is applied to and cured on the border area in such a way that it extends along the whole or parts of the border area and is arranged to form a gasket for tight abutment against an adjacent plate in the plate heat exchanger.

By means of such a heat exchanger plate, the disadvantages which are mentioned above may be remedied. The plate may be manufactured in an easy manner by applying the polymer material in a viscous uncured state to the plate in the border area and thereafter curing the material. When the polymer material has been cured, a heat exchanger plate, on which the polymer material is fixedly attached to the border area and which may be provided adjacent to another such plate in a plate package is obtained. The mounting of the previously used complete gaskets may thus be dispensed with. The manufacturing may in an easy manner be automatised since the viscous polymer material may be applied by means of a robot.

According to an embodiment of the invention, the curable polymer material includes silicon, which has good sealing properties. Silicon also has a high adhesion capability to the underlying heat exchanger plate. Advantageously, the curable polymer material may include Liquid Silicon Rubber, LSR.

According to a further embodiment of the invention, the curable polymer material after curing forms a lower, substantially plane surface, which is attached directly to the border area. Thus a good adhesion to the border area of the underlying plate is ensured. Furthermore, the curable polymer material may after curing include an upper surface which in a cross-section has a softly curved, convex shape. By such a convex shape, a tight abutment against the adjacent plate is ensured. This abutment will due to the convex shape have an approximately linear shape. The convex shape also contributes to a relatively small risk that the gasket will be attached to the adjacent plate, in particular in comparison with the adhesion to the border area of the underlying plate also after a long time of use. The plate package may thus in an easy manner be dismounted.

According to a further embodiment of the invention, the curable polymer material includes a first component and a second component, which are mixed to an applicable polymer mixture. Such curable polymer materials may be stored during a long time before the components are mixed. Such curable polymer materials may be given desired properties regarding adhesion capability, viscosity, hardness after curing etcetera. Advantageously, the applicable polymer mixture is before curing highly viscous, wherein the polymer mixture may be applied in an easy manner. For instance, the applicable polymer mixture may have a viscosity which amounts to between 300 and 800 Pas (Pascal x second). By such a viscosity, it may be ensured that the polymer mixture maintains a desired shape before the curing and until the curing is finished. At the same time it is possible, with a viscosity in this order, to ensure that the joint between the beginning of the applied material and the end thereof becomes sufficiently uniform. The selected viscosity thus has to be optimised with regard to at least the application capability, shape stability and joint uniformity.

According to a further embodiment of the invention, the border area includes a bottom surface along substantially the whole border area and at least a first side surface which extends along the whole

border area and between the bottom surface and the heat transfer area. The first side surface may be broken in the sense that a break arises where the corrugation of the heat transfer area reaches the first side surface. The first side surface forms an angle to the bottom surface. In such a way a marked path for the polymer material is formed. The border area may also include a second side surface which extends along the whole border area outside the bottom surface, wherein the second side surface forms an angle to the bottom surface. The polymer material will thus be enclosed between the side surfaces and kept in the desired position also after a long time of use of the plate heat exchanger. The heat exchanger plate may also include an edge area, which is located outside the border area and which extends around and delimits the border area, wherein the second side surface extends between the bottom surface and the edge area.

The object is also achieved by the initially defined plate heat exchanger, which includes a package of heat exchanger plates of the type defined above. Such heat exchanger plates may in an easy manner be mounted to a plate package of the plate heat exchanger, wherein the plate package is kept together by means of tie bolts or any similar members.

The object is also achieved by the initially defined method which is characterised by the step of:
application of a curable polymer material to the border area in such a way that it extends along the whole or parts of the border area, and
curing the polymer material for forming of a gasket for tight abutment against an adjacent plate in the plate heat exchanger.

Advantageous embodiments of the method are defined in the dependent claims 15 to 25.

Advantageously, the curable polymer material includes a first component and a second component, wherein the method substantially immediately before said application includes the step

of mixing the two components to an applicable preferably highly viscous polymer mixture. The first component may include silicon, for instance LSR, and possibly a catalyst, and the second component silicon, for instance LSR, and an activator, for instance in the form of a cross-linking agent, wherein the percentages of the two components in the polymer mixture are substantially equal. The viscosities of the two components are advantageously substantially equal.

Furthermore, the curable polymer material may be applied by means of an automatic handling device arranged to carry a nozzle for the discharge of the polymer material and for guiding the nozzle along the border area. After the application, the curable polymer material may be cured at a raised temperature, for instance between 150°C and 250°C. The polymer material may be cured during a curing time which amounts to at least 0,5 h.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is now to be explained more closely through a description of various embodiments, disclosed by way of example, and with reference to the drawings attached hereto.

Fig 1 discloses schematically a side view of a plate heat exchanger according to the invention.

Fig 2 discloses schematically an elevation view of the plate heat exchanger in Fig 1.

Fig 3 discloses schematically an elevation view of the heat exchanger plate of the plate heat exchanger in Fig 1.

Fig 4 discloses a cross-sectional view along the line IV-IV in Fig 3.

Fig 5 discloses schematically a handling device for the application of a polymer material to the plate in Fig 3.

DETAILED DESCRIPTION OF VARIOUS EMBODIMENTS OF THE INVENTION

Figs 1 and 2 disclose a plate heat exchanger 1 including a plate package 2 with heat exchanger plates 3 that are arranged adjacent to each other. The package is provided between two end plates 4 and 5. The end plates 4 and 5 are pressed against the plate package 2 and each other by means of tie bolts 6 extending through the end plates 4 and 5. The tie bolts 6 include threads and the plate package 7 may thus be compressed by threading nuts 7 onto the tie bolts 6 in a manner known per se. In the embodiment disclosed, four tie bolts 6 are indicated. It is to be noted that the number of tie bolts may vary and be different in different applications.

The plate heat exchanger 1 also includes two inlet members 8 and two outlet members 9. The inlet and outlet members 8, 9 extend through one of the end plates 5 and the plate package 3. The plates 3 are in a manner known per se provided with portholes 10, see Fig 3, and compression-moulded in such a way that every second interspace between adjacent heat exchanger plates 3 communicate with a first pair of inlet and outlet members 8, 9 whereas every other interspace between adjacent heat exchanger plates 3 communicates with the other pair of inlet and outlet members 8, 9. Such a separation of the interspaces may be obtained by pressing the plates in such a way that the area around the portholes 10 substantially is positioned at a middle plane of the heat exchanger plate 3. The portholes 10 may also be surrounded by gaskets for obtaining this separation of the interspaces. These gaskets are to be explained more closely below.

~~Consequently, a first medium may be introduced through a first inlet~~ member 8, through a first half of the plate interspaces and out through a first outlet member 9. A second medium may be introduced through a second inlet member 8, through the second half of the plate interspaces and out through the second outlet member 9. The two media may be conveyed in a counterflow or in parallel flow to each other.

With reference to Figs 3 and 4, the configuration of the individual heat exchanger plates 3 is now to be explained. Fig 3 discloses an elevation view of a heat exchanger plate 3. The heat exchanger plate 3 is manufactured of a metal sheet, preferably stainless steel, and includes a substantially central heat exchanger area 20 in which the portholes 10 mentioned above are provided. The heat transfer area 20 is in a manner known per se provided with a corrugation 21, which is obtained through compression-moulding of the metal sheet. In the embodiment disclosed, the corrugation 21 is merely indicated schematically as extending diagonally over the heat transfer area 20. It is to be noted that the corrugation 21 may include significantly more complex extensions of the ridges and valleys, for instance along the herringbone pattern known per se. Also substantially completely plane plates may be used within the scope of this invention.

The heat exchanger plate 3 also includes a border area 22 which is located outside the heat transfer area 20 and which extends around and delimits the heat transfer area 20. The heat exchanger plate 3 also includes an edge area 23 which is located outside the border area 22 and which extends around and delimits the border area 22. As appears from Fig 2, the border area 22 includes a bottom surface 25 which extends along substantially the whole border area 22 and a first side surface 26 which extends along the border area 22 and between the bottom surface 25 and the heat transfer area 20, and a second side surface 27 which extends along the whole border area 22 between the bottom surface 25 and the edge area 23. The first side surface 26 may be broken where the corrugation of the heat transfer area 20 reaches the first side surface 26. The side surfaces 26, 27 form a respective angle to the bottom surface 25. The border area 22 thus, in the embodiment disclosed, has a groove-like design with a trapezoid-like shape in a cross-section.

Each heat exchanger plate 3 includes a gasket 30 which is provided in the border area 22 and which thus extends along the heat transfer area 20. In the embodiment disclosed, the gasket 30

extends along substantially the whole border area 22 with the exception of four interruptions, which form drainage passages 34 in the proximity of the two portholes 10. Fig 4 discloses a cross-sectional view of the gasket 30. The gasket 30 includes a substantially plane lower surface 31 which abuts the substantially plane bottom surface 25 of the border area 22. The gasket 30 may also abut and be supported by the side surfaces 26, 27 of the border area 22. The gasket 30 also exhibits an upper surface 32 which in a cross-section has a softly curved, convex shape. Consequently, the gasket 30 in the mounted plate package 2 with the upper surface 32 abuts an adjacent heat exchanger plate 3' with a force concentration along a centre line.

The gasket 30 is formed by a curable polymer material. The polymer material is supplied in the border area in an uncured state as a highly viscous polymer mixture with a viscosity which amounts to between 300 and 800 Pas, preferably 450-650 Pas. By such a viscosity, the polymer mixture may easily be applied and after the application obtain the cross-sectional shape disclosed in Fig 4. At the same time, it is possible with such a viscosity to prevent that the polymer material is too viscous and forms irregularities, especially in joints between the beginning of the gasket and the final end of the gasket 30.

Fig 5 discloses schematically an automatic handling device for application of the polymer material. The handling device includes a robot arm 40 with a gripping member 41 which holds an application member 42. The application member 42 includes a mixing chamber 43 and a nozzle 44 for discharge of the polymer material. The robot arm 40 may in a manner known per se be programmed to follow a determined movement path, in this case along the indicated border area 22.

The curable polymer material includes suitably silicon and in the embodiment disclosed Liquid Silicon Rubber, LSR, is used. The polymer material is provided as a first component, including LSR and possibly a catalyst, and a second component including LSR

and an activator, for instance in the form of a cross-linking agent. The two components are supplied to the mixing chamber 43 via a respective supply conduit 45, 46, and are thus mixed in the mixing chamber 43 substantially immediately before the polymer mixture is supplied to the heat exchanger plate 3 via the nozzle 44. After the application of the polymer mixture, the polymer mixture is cured. The curing may be performed in room temperature during a relatively long time period, but is preferably performed in a curing oven at a temperature of between 150°C and 250°C, for instance about 200°C. The curing time may amount to between 30 min and 2 hours, for instance about 1 hour. After the curing, the gasket 30 has a suitable hardness which permits tight abutment against the plate 3' provided thereabove without the risk of strong adhesion to the plate 3' provided thereabove. After the curing, the gasket 30 is fixedly attached to the underlying plate 3.

Each heat exchanger plate 3 may also, as mentioned above, include a gasket 50 delimiting two of the portholes 10. Furthermore, a further gasket 51 may be arranged around each porthole 10 immediately in the proximity of the edge of the porthole 10. These gaskets 50 and 51 may be manufactured in the same way and substantially at the same time as the gasket 30. The gaskets 50 and 51 thus have the same properties as the gasket 30.

The invention is not limited to the embodiments described above but may be varied and modified within the scope of the following claims.

For instance, the heat exchanger plate 3 may be used in various plate heat exchanger applications and include fewer or more than the portholes disclosed. Furthermore, the invention is applicable to plate heat exchangers without portholes, wherein the inlet members and the outlet members may connect to different sides of the plate package.

It is to be noted that the expressions "below" and "above", which is used in this application, merely refer to the position in relation to

the gasket 30, 50 as disclosed in the drawings. When the plate heat exchanger 1 then is used, the plates 3 may of course have another orientation.